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EFFICACY OF USING RADIO TRANSMITTERS TO MONITOR LEAST TERN CHICKS

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ABSTRACT.—Little is known about Least Tern (*Sterna antillarum*) chicks from the time they leave the nest until fledging because they are highly mobile and cryptically colored. We evaluated the efficacy of using radio-telemetry to monitor Interior Least Tern (*S. a. athalassos*) chicks at Salt Plains National Wildlife Refuge, Oklahoma. In 1999, we attached radio transmitters to 26 Least Tern chicks and tracked them for 2–17 days. No adults abandoned their chicks after transmitters were attached. Transmitters did not appear to alter growth rates of transmittered chicks ($P = 0.36$) or prevent feather growth, although dermal irritation was observed on one chick. However, without frequent reattachment, transmitters generally did not remain on chicks <1 week old for more than 2 days because of feather growth and transmitter removal, presumably by adult terns. Although the presence of transmitters did not adversely affect Least Tern chicks, future assessments should investigate nonintrusive methods to improve retention of transmitters on young chicks and reduce the number of times that chicks need to be handled. *Received 27 May 2004, accepted 30 December 2004.*

Survival estimates for endangered Least Tern (*Sterna antillarum*) chicks—from hatching until fledging—are obtained primarily through indirect measures, such as ratios of observed number of fledged birds to number of successful nests (Kirsch 1996, Woodrey and Szell 1998) or estimated number of breeding pairs (Schwalbach et al. 1993). Direct measurements of survival and determining the factors that impact survival have been hindered because Least Tern chicks are semi-precocial, highly mobile, and cryptically colored. Furthermore, Least Terns nest colonially in open habitats, making undetected approach difficult. Approaches within 250 m result in alarm calls from adults, and, at that distance, chicks are difficult to see. Dugger et al. (2000) successfully used a mark-recapture technique to estimate survival of Interior Least Tern chicks (*S. a. athalassos*) nesting on islands. Because Least Tern chicks may move freely, mark-recapture techniques would be less useful in expansive nesting habitats (e.g., salt flats) than in restricted habitats (e.g., islands). In either case, neither method can reveal factors that affect survival of individual chicks. Accurate estimates of chick survivorship and cause-specific mortality are essential for determining management strategies to improve productivity of this endangered species (U.S. Fish and Wildlife Service 1990).

With varying success, adult Least Terns have been marked with patagial tags and radio transmitters. Brubeck et al. (1981) detected high rates of nest desertion after attaching patagial tags, but it was unclear whether the desertions were due to extended handling times or the tags. In two studies, adhesives were used to attach transmitters onto the backs of adult Least Terns (Massey et al. 1988, Hill and Talent 1990). In the 2-year study by Massey et al. (1988), terns marked in year one ($n = 4$) were slow to return to their nests (>4 hr before return), and all terns marked in year two ($n = 3$) exhibited various degrees of abnormal incubation and abandonment. In contrast, Hill and Talent (1990) found faster return rates (≤70 min) and several transmittered individuals resumed incubation immediately (some terns were trapped but not transmittered). Nest desertion and nest and egg survival for radio-transmittered terns ($n = 20$ terns, $n = 15$ nests) did not differ from the control group (Hill and Talent 1990).

Advances in radio-telemetry equipment have facilitated monitoring of small birds (Sykes et al. 1990, Yalden 1991). Previously, radio transmitters could be used only on mid- to large-sized animals because transmitter weights were excessive. Currently, one can

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obtain transmitters that weigh <1.0 g and have a battery life of about 21 days. The life span of small transmitters limits their use for long-term monitoring of individuals, but Least Tern chicks fledge at about 20 days (Thompson et al. 1997); therefore, transmitter life is generally long enough to confirm survival to fledging.

We evaluated the efficacy of radio-telemetry to monitor Least Tern chicks from hatching until fledging by assessing the impact of carrying radio transmitters. We also report on the technical details of this method.

METHODS

Study area.—Our study was conducted from 1 June to 15 August 1999 at Salt Plains National Wildlife Refuge (SPNWR), Alfalfa County, Oklahoma (98° 15′ N, 36° 43′ W). At this refuge, Least Terns nest on a salt flat of about 5,000 ha adjacent to Great Salt Plains Reservoir (Koenen et al. 1996). The nesting habitat is nearly level and has little vegetative cover, making detection distance of transmitter signals nearly optimal. We selected a study site at the south end of the Least Tern nesting habitat.

Nest location.—We located nests by searching defended territories. To reduce disturbance, we initially located nests from outside defended areas by observing adults returning to nests. If the number of potential pairs exceeded the number of nests, we conducted a systematic search of the surrounding area to locate additional nests. We marked nests with a numbered dowel placed about 10 m away from the nest cup. Dowels were placed in random directions to discourage a learned response by predators. Nests were examined visually from about 5 m away every 3–10 days until hatching. Nests that showed signs of disturbance (i.e., missing or broken eggs, etc.) were examined physically to determine cause of disturbance.

Radio-marked chicks.—Chicks (ages 1–3 days) were placed into a mesh bag, weighed with a hanging spring scale, and then banded with U.S. Fish and Wildlife Service aluminum leg bands. Radio transmitters were placed on the largest chick in each nest at about 2–3 days of age; we also fitted transmitters on three chicks found away from their nests. As a precautionary measure, we hooded captured chicks to reduce stress (Hill and Talent 1990). Except for the type of glue used, we followed the transmitter attachment technique used by Hill and Talent (1990). Because cyanoacrylate glues have been linked with skin irritation and impaired skin functioning (i.e., blocked skin pores; Johnson et al. 1991), we used latex-based surgical glue (Skin Bond, Smith and Nephew, London, United Kingdom). We attached transmitters by first clipping down feathers of the interscapular region to expose the skin; then, surgical glue was brushed onto both the bare skin of the chick and the base of the transmitter. After the transmitter was in position, it was held in place for 1 min to seal the bond. When possible, surrounding feathers were glued over the top of the transmitter for camouflage and to reduce the likelihood of the transmitter being removed. Glue-on techniques have advantages over harnesses because attachment is easier (Sykes et al. 1990) and harnesses have been found to alter behavior and survival in some birds (Kenward 1987, Hubbard et al. 1998). Using a mild solvent, we removed transmitters from chicks by 17 days of age to avoid hampering chicks during fledging.

We attached 16 L.L. Electronics transmitters (model SMT-1-379-RS-T; Mahomet, Illinois) and 10 Holohil Systems Ltd. transmitters (model LB–2; Woodlawn, Ontario, Canada) to 26 chicks. Estimated life span of the transmitters was 2–3 weeks. L.L. Electronics transmitters averaged 0.8 g and measured 0.9 × 0.6 × 0.4 cm. Holohil transmitters averaged 0.6 g and measured 1.1 × 0.6 × 0.2 cm. Transmitter weight at the time of attachment was 5–8% of a chick's weight (greater than the 3% benchmark recommended by the North American Bird Banding Laboratory but less than the 10% maximum recommended by Gaunt et al. 1997), but by 6 days of age, transmitter weight was ≤3% of chick weight. All monitoring and handling protocols were approved under U.S. Fish and Wildlife Service Endangered Species Permit TE820283-1.

Radio-tracking.—The first three chicks fitted with transmitters were located once every 24 hr. When a transmitter was found to be loose, it was reattached. Because transmitters frequently became loose or detached, we located, captured, and physically examined the remainder of the chicks every 12 hr.

Chicks were tracked during morning and evening hours, when temperatures were <35° C. We never tracked chicks during rainstorms. Once a week, we recaptured and weighed all chicks. When transmitters were removed, skin and feather condition were examined for damage.

We calculated a growth curve for transmittered chicks by weighing them weekly. Few chicks without transmitters could be found again at SPNWR; thus, growth rates of transmittered chicks could not be compared with those of untransmittered chicks from the same location. Because we were unable to locate published data on daily growth rates of Interior Least Tern chicks, we used growth data from California Least Tern (*S. a. browni*) chicks that also were captured and handled daily (Massey 1974) to estimate the impact of transmitters on growth of SPNWR chicks. We compared the straight-line segment between day 4 and 16 of each growth curve and intercepts using ANCOVA with chick age as the covariate (SAS Institute, Inc. 1996).

RESULTS

We attached radio transmitters to 26 Least Tern chicks. Because of flooding and predation on the alkaline flat, loss of tern nests was common (e.g., Winton and Leslie 2003). Of 17 nests located in June 1999, 10 were lost before hatching and only three chicks were marked from 22 to 28 June. After adults renested, 23 additional chicks were marked from 24 July to 7 August 1999. Processing time per chick averaged 16 min ± 1.0 SE. No chicks were deserted or left unattended by adults after transmitters were attached. All chicks appeared to move normally after the transmitter was attached (Whittier 2001).

Our initial intent was to refind chicks once a day to evaluate their condition and transmitter attachment, but, of the three chicks marked in June, only one was found again and its transmitter had to be reattached twice before it was 5 days old (Table 1). The other two June chicks presumably lost their transmitters and could not be found again. Therefore, we changed our protocol to relocate chicks twice a day; transmitters were reattached whenever a light tug on the transmitter antenna revealed a partially detached transmitter. Four of 26 chicks were not found again or died after 1 day and 4 (15%) retained their transmitters without reattachment for 3 (n = 2), 7, and 8 days (Table 1). Transmitters requiring reattachment were prevalent in the young age classes; 18 of 26 chicks (69%) ≤4 days of age were found with partially detached transmitters (Table 1). Transmitters on these 18 chicks had to be reattached, but the number of necessary reattachments decreased as the number of monitoring days increased (Fig. 1).

Growth of chicks at SPNWR was sigmoidal (r^2 = 0.95; Fig. 2) and averaged 2.2 g/day. Based on growth curves, predicted fledging weight of chicks at SPNWR was 40 g (assuming fledging at 20 days; Thompson et al. 1997); chicks in California weighed 40.5 g at fledging (Massey 1974). A comparison of growth rates of transmittered chicks (n = 20) at SPNWR with untransmittered chicks (n = 152) in California (Massey 1974) demonstrated that chick weight at 4 days of age (our study: 11.25 g ± 1.76 SE; California: 13.81 g ± 0.28 SE; ANCOVA, $F_{1,24}$ = 4.64, P = 0.043) differed, but mean growth rate did not differ (our study: 2.3 g/day; California: 2.4 g/day; $F_{1,24}$ = 0.17, P = 0.69; Fig. 2). Massey (1974) noted that weight gain and absolute weight of California tern chicks stabilized at about day 15 and varied between 35 and 40 g; chicks of the same age at SPNWR weighed between 36 and 39 g.

We examined physical condition and feather growth when we removed transmitters from chicks that died (n = 6) or were near fledging (n = 7). Those individuals carried a transmitter for a mean of 9 days. Two chicks fledged before we removed the transmitters and the remainder disappeared (Table 1). Only one chick exhibited any sign of skin irritation; the skin was light pink, indicating only mild irritation, and that chick successfully fledged. Two of the dead chicks did not exhibit any obvious signs indicating cause of death. The other four deaths were attributed to predation, flooding, or unusual exposure (one individual was unable to escape from a deep hoofprint). Feather growth was not impaired on any of the chicks, and feathers were not visibly damaged. Feather growth under the transmitter shifted the transmitter to a lower position on the back.

TABLE 1. Patterns of radio-transmitter retention for 26 Least Tern chicks in northcentral Oklahoma, June–August 1999. We often found chicks with partially detached transmitters that had to be reattached, but the frequency of occurrence decreased with chick age.

	Age of chick (days)			No. of reattachments by age group in days					
Chick no.	Transmitter attachment	Transmitter removal	No. of days monitored	2–4	5–8	9–12	13–17	Total no. of reattachments	Chick fate
June captures: monitored once/day									
1	2	NA[a]	1					0	Unknown
2	2	NA	4	2	0			2	Unknown
3	1	NA	1					0	Unknown
July–August captures: monitored twice/day									
4	2	NA	8	2	0	0		2	Unknown
5	1	NA	12	2	0	0		2	Unknown
6	2	5	3	0				0	Dead
7	2	NA	3	3				3	Unknown
8	2	NA	3	2				2	Unknown
9	4	NA	15	1	1	2	1	5	Fledged
10	2	10	8	2	1	0		3	Dead
11	1	2	1					0	Dead
12	1	NA	4	3				3	Unknown
13	2	17	15	2	1	2	0	5	Fledged
14	1	17	16	3	1	2	0	6	Unknown
15	2	5	3	1				1	Dead
16	2	13	11	2	1	0		3	Dead
17	3	16	13	1	1	1	0	3	Unknown
18	2	NA	3	2				2	Unknown
19	2	NA	1					0	Unknown
20	2	NA	8	2	1	0		3	Unknown
21	Unk[b]	NA	8					0	Fledged
22	Unk	Unk	3					0	Dead
23	2	NA	9	1	1	1		3	Unknown
24	Unk	NA	7					0	Unknown
25	2	15	13	3	0	1	0	4	Unknown
26	2	14	12	1	1	1	0	3	Unknown

[a] Not applicable: not all transmitters were removed from chicks; several individuals disappeared and two flew away with the transmitter still attached.
[b] Chick age was unknown when transmitter was attached.

DISCUSSION

Radio telemetry is a reliable technique for ascertaining life-history traits of precocial and semi-precocial chicks. Various transmitter-attachment methods have been investigated for birds, including subcutaneous implants, suture and prongs, sutures, harnessed backpacks, and adhesives (Samuel and Fuller 1994, Korschgen et al. 1996, Hubbard et al. 1998, Davis et al. 1999, Burkepile et al. 2002). We do not recommend implants or either suture technique for endangered Least Tern chicks because those methods are invasive and some have led to infections (Burkepile et al. 2002). Based on apparent efforts of Least Tern adults or chicks in our study to physically remove transmitters, suture methods could result in increased stress and physical trauma to chicks. Hubbard et al. (1998) recommended not using harnessed backpacks on chicks because reduced blood circulation to the wings can lead to impaired wing development that potentially could prevent flight. Adhesive methods have the advantage of (1) short handling time, (2) imposing minimal physical impairment to an individual's movement, (3) requiring no medical procedures, (4) being noninvasive, (5) minimizing the chance of infection, and (6) not causing growth impairment.

Ideally, the impact of carrying transmitters should be assessed using a reference group within the same study area (White and Garrott 1990). However, chicks at SPNWR are difficult to refind on the expansive salt flats. Dur-

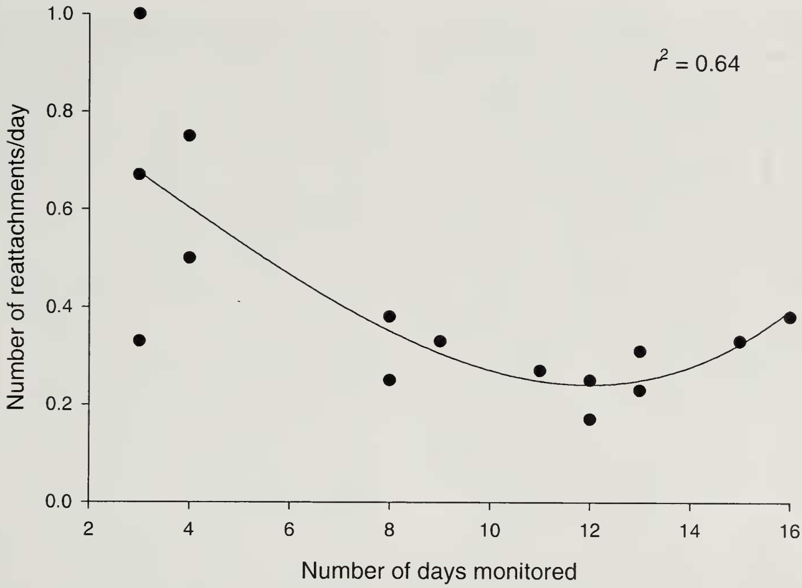

FIG. 1. Relationship between the number of days monitored and the number of reattachments necessary per day for 18 of 26 Least Tern chicks in northcentral Oklahoma, June–August 1999 (transmitters on the remaining 8 chicks were not reattached; 4 of these chicks disappeared after 1 day of monitoring).

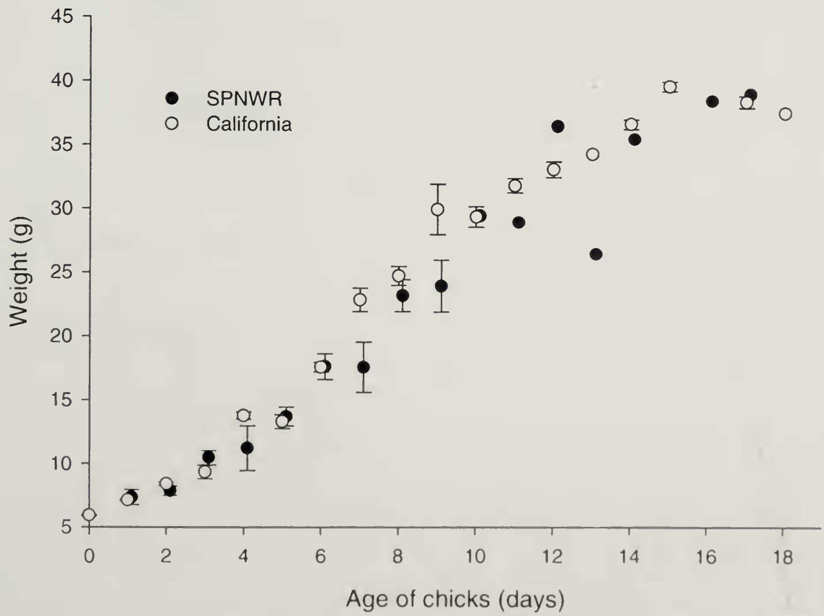

FIG. 2. Growth curves (mean weight ± SE) of radio-transmittered Interior Least Tern chicks at Salt Plains National Wildlife Refuge, Oklahoma, and non-transmittered California Least Tern chicks (Massey 1974). At both sites, chicks were captured and handled at least once a day.

ing our study, we were unable to locate banded, untransmittered chicks or siblings of transmittered individuals. Because no detailed data were found in published literature for growth rates of Interior Least Terns, we used growth data for chicks without transmitters in California (Massey 1974). Although comparing weights of geographically disjunct populations is not ideal, we found that growth rates did not differ statistically between study groups. Frequent disturbance (up to two times per day to examine chicks and transmitters) did not prompt adult Least Terns to abandon their offspring or leave them unattended after we departed the immediate vicinity. The Kaplan-Meier estimate of survival for the transmittered chicks was 26% (Whittier 2001), which falls within the range of survival-to-fledging estimates (19–69%) for Least Tern chicks in northwestern Oklahoma (Schweitzer and Leslie 2000).

The majority of avian telemetry studies are conducted on adult or fledged birds, probably because of limitations related to transmitter weight. For this reason, little is known about the impact of the adhesive attachment technique on feather growth. Although several studies of precocial chicks have entailed using adhesives as an attachment method, or using adhesives in conjunction with another method, no mention was made of feather growth (Yalden 1991, Burkepile et al. 2002). Our results indicate that surgical glue did not disrupt feather growth in Least Tern chicks; after the glue was removed using a mild solvent, feathers were not visibly damaged. Dermal irritation was observed on only one chick, and that individual had worn its transmitter for 17 days. The low level of dermal irritation observed in this study was consistent with the findings of Sykes et al. (1990), who examined use of adhesives to attach transmitters to small passerines.

Transmitter loss was greatest when chicks were ≤4 days of age, but it also occurred in older age classes—albeit with decreasing frequency. Feather growth caused transmitters to lift from the skin and shift posteriorly down the chicks' backs. Despite transmitters shifting away from the center of gravity, transmittered chicks were able to run normally. The tendency for feather growth to move the transmitter likely contributed to the poor retention of transmitters. Increased retention of transmitters appeared to coincide with the development of pinfeathers. Transmitters were loosened anteriorly, evidently because either parents or chicks tugged on the antennae.

Survivorship and the factors that impact survival are difficult to determine for precocial and semi-precocial chicks because they are difficult to refind. Advancements in transmitter technology have enabled production of smaller transmitters with weights that are reasonable for Least Tern chicks to carry. Those advancements provide the opportunity to more accurately assess chick survivorship and examine variables that impact survivorship for small semi-precocial chicks. Latex surgical adhesive appears to be a safe method of transmitter attachment for Least Tern chicks because it did not irritate the skin, impair feather growth, or damage feathers; however, future research should investigate methods to improve retention of transmitters. Chick growth and movement were not impaired by the presence of a transmitter.

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